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Grand Lake O' The Cherokees Ottawa, Mayes, Delaware, and Craig Counties, Oklahoma

National Eutrophication Survey, Las Vegas, Nev

Prepared for

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NATIONAL EUTROPHICATION SURVEY

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

GRAND LAKE O' THE CHEROKEES

OTTAWA, MAYES, DELAWARE, AND

CRAIG COUNTIES, OKLAHOMA

EPA REGION VI

WORKING PAPER No. 589

WITH THE COOPERATION OF THE

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AND THE

OKLAHOMA NATIONAL GUARD

MARCH, 1977

REPORT ON GRAND LAKE O' THE CHEROKEES

OTTAWA, MAYES, DELAWARE, AND CRAIG COUNTIES, OKLAHOMA

EPA REGION VI

by

National Eutrophication Survey

Water and Land Monitoring Branch
Monitoring Applications Laboratory
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Las Vegas, Nevada

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [s303(e)], water quality criteria/standards review [s303(c)], clean lakes [s314(a,b)], and water quality monitoring [s106 and s305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Oklahoma Department of Pollution Control for professional involvement, to the Oklahoma National Guard for conducting the tributary sampling phase of the Survey, and to those Oklahoma wastewater treatment plant operators who provided effluent samples and flow data.

Dr. Denver Talley, Director, Oklahoma Department of Pollution Control; the staff of the Oklahoma Water Resources Board; and the staff of the Oklahoma State Department of Health reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper Series.

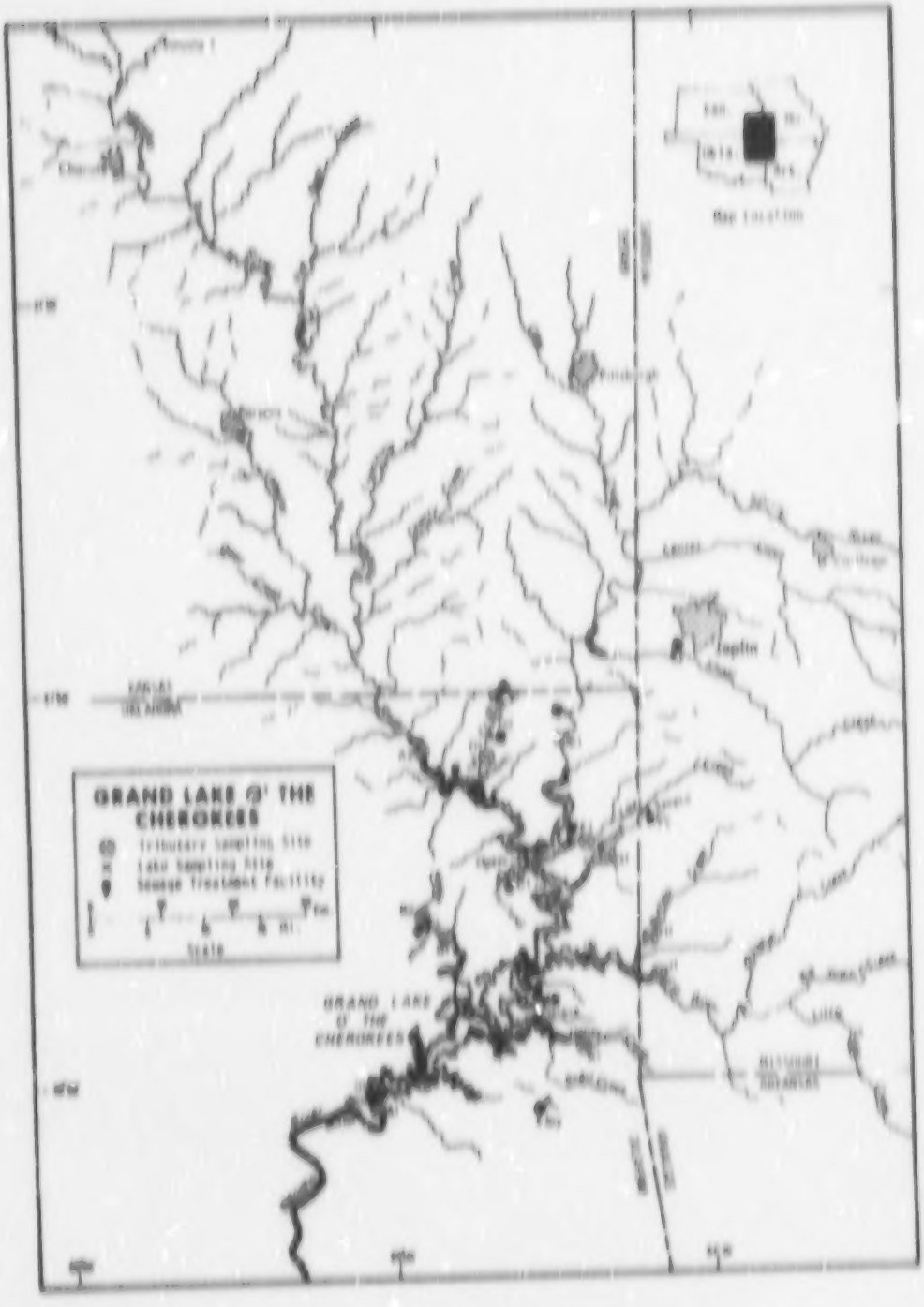
Major General John Coffey, Jr., the Adjutant General of Oklahoma, and Project Officers Colonel Curtis W. Milligan and Major James O. Haney, Jr., who directed the volunteer efforts of the Oklahoma National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF OKLAHOMA

LAKE NAME	COUNTY
Altus Reservoir	Greer, Kiowa
Arbuckle Lake	Murray
Lake Elsworth	Caddo, Comanche
Lake Eufaula	Haskell, McIntosh, Okmulgee, Pittsburg
Fort Cobb Reservoir	Caddo
Fort Supply Reservoir	Woodward
Foss Dam Reservoir	Custer
Lake Frances	Adair
Grand Lake O' The Cherokees	Mayes, Delaware, Craig Ottowa
Lake Hefner	Oklahoma
Keystone Reservoir	Tulsa, Creek, Osage, Pawnee
Oologah Lake	Nowata, Rogers
Tenkiller Ferry Reservoir	Cherokee, Sequoyah
Lake Thunderbird	Cleveland
Wister Reservoir	Leflore


GRAND LAKE O' THE CHEROKEES
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Joplin
GRAND LAKE O' THE CHEROKEES

REPORT ON GRAND LAKE O' THE CHEROKEES

STORET NO. 4009

I. CONCLUSIONS

A. Trophic Condition:*

Grand Lake o' the Cherokees is considered eutrophic, i.e., nutrient rich and highly productive, on the basis of field observations and Survey data. Whether such nutrient enrichment is to be considered beneficial or deleterious is determined by its actual or potential impact upon designated beneficial water uses of each lake.

Nutrient levels in the lake were extemely high; of the 16 Oklahoma lakes (including Lake Texoma) sampled in 1974, only 2 had higher median total phosphorus levels, 1 had higher median inorganic nitrogen values, and 2 had higher median orthophosphorus levels than Grand Lake. Chlorophyll a levels in the lake ranged from 0.4 µg/l to 26.9 µg/l, with a mean of 6.8 µg/l. Potential for primary production as measured by algal assay control yields was high on all sampling occasions.

Survey limnologists reported no problem algal blooms or aquatic macrophyte growths during their visits to the lake. However, low Secchi disc values in the lake coupled with high nutrient levels suggest primary productivity is light-limited in Grand Lake o' the Cherokees during much of the year.

*See Appendix E.

B. Rate-Limiting Nutrient:

Algal assay results for Stations 01-04 in Grand Lake o' the Cherokees indicate that nitrogen was the primary limiting nutrient in the spring, and phosphorus the limiting nutrient at Stations 05-07 at that time. The autumn assay suggest phosphorus limitation. The lake data indicate phosphorus limitation at all sampling times. However, primary growth limitation is more likely due to low light than limiting nutrient levels.

C. Nutrient Controllability:

1. Point sources -

During the sampling year, point sources were estimated to contribute approximately 3.7% of the total phosphorus load to Grand Lake o' the Cherokees. The city of Miami contributed approximately 1.1% from four municipal and industrial plants, and the city of Joplin contributed 0.6%.

The present overall phosphorus loading of 6.90 g $P/km^2/yr$ is about six times that proposed by Vollenweider (1975) as "eutrophic" for lakes with such volume and hydraulic retention time. In addition to the known point sources impacting Grand Lake o' the Cherokees, Ketelle and Uttormark (1971) report that large quantities of nutrients enter the lake from feedlot runoff in Kansas, a poultry boiler production in southwestern Missouri, and septic tank drainage from residences around the lake.

houseboats, and other pleasure craft. Also included in the loading for the lake are upstream municipal and industrial sources (such as those from the city of Carthage) not presented in the lake nutrient budget due to their distance from the reservoir, and at least one fish hatchery (impacting Shell Creek) for which no nutrient loading data is available. The loading data indicate that total elimination of known point sources would still leave high nutrient inputs, and further reduction in nutrient contributions, including nonpoint, would probably be necessary to affect demonstratable water quality improvement.

2. Nonpoint sources -

The total annual phosphorus load not attributable to nearby point sources was about 96.3% of the total reaching the lake. The Neosho River contributed 62.7%, the Spring River contributed 28.2%, and ungaged minor tributaries and immediate drainage were estimated to have contributed 1.2%.

The annual phosphorus export rates for several of the tributaries to Grand Lake o' the Cherokees were inordinately high. In the cases of Horse Creek (B-1) and Tar Creek (D-1), these high export rates probably have resulted from underestimation of the point source contributions impacting each creek. In the Neosho River (A-2) and Spring Creek (E-1), high background loadings may be due to upstream unidentified and/or unmeasured point sources rather than nonpoint contribution.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake surface area and mean depth were provided by the Oklahoma Department of Pollution Control; maximum depth was provided by the Oklahoma Water Resources Board. Tributary flow data were provided by the Oklahoma District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 100.18 km^2.
2. Mean depth: 10.9 meters.
3. Maximum depth: 50.0 meters.
4. Volume: 2,051.162 x 10^6 m^3.
5. Mean hydraulic retention time: 129 days.

B. Tributary and Outlet:
(See Appendix B For Flow data)

1. Tributaries -

Name	Drainage area(km²)	Mean flow (m³/sec)
A-2 Neosho River	15,218.6	100.55
E-1 Horse Creek	64.5	0.46
D-1 Tar Creek	88.8	0.55
I-1 Spring River	6,682.2	51.81
F-1 Lost Creek	233.4	1.65
H-1 Buffalo Creek	260.5	1.90
J-1 Elk River	2,266.5	21.36
K-1 Honey Creek	124.1	0.88
Minor tributaries and immediate drainage -	1,562.6	15.52
Totals	26,483.4	194.68

2. Outlet - A-1 Neosho River 26,671.5 183.86

C. Precipitation:

1. Year of sampling: 139.2 cm.
2. Mean annual: 106.8 cm.

III. LAKE WATER QUALITY SUMMARY

Grand Lake o' the Cherokees was sampled four times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from seven stations on the lake and from a number of depths at each station (see map, page v). During each visit, depth-integrated samples were collected from each station for chlorophyll a analysis and phytoplankton identification and enumeration. During the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths sampled were 37.2 meters at Station 01, 27.4 meters at Station 02, 20.7 meters at Station 03, 18.3 meters at Station 04, 14.3 meters at Station 05, 9.1 meters at Station 06, and 7.6 meters at Station 07. For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll a determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

SPRING LAKE AT THE OUTLET
STUDY CODE 4021

PHYSICAL AND CHEMICAL CHARACTERISTICS

PARAMETER	NP	AVG	MIN	MAX	NP	AVG	MIN	MAX	NP	AVG	MIN	MAX
TEMPERATURE (DEG C)(AT)												
0.=1.5 M DEPTH	24	13.4	15.1	12.2	8.0	1.5	24	23.8	25.0	24.4	8.0	1.5	13	25.2	26.2	25.6	8.0	1.5
MAX DEPTH	7	4.7	14.1	11.4	7.0	36.0	7	13.5	25.0	24.0	7.0	37.2	7	24.4	25.0	25.1	4.0	35.1
DISSOLVED OXYGEN (MG/L)																		
0.=1.5 M DEPTH	7	8.8	9.6	8.5	1.5	1.5	24	9.2	11.3	8.2	8.0	1.5	13	9.2	8.6	9.4	8.0	1.5
MAX DEPTH	7	8.8	11.2	8.6	7.0	36.0	7	2.8	9.4	4.8	7.0	37.2	7	7.4	9.6	8.2	4.0	35.1
CONDUCTIVITY (UMHOS)																		
0.=1.5 M DEPTH	24	385.	394.	288.	8.0	1.5	24	288.	334.	335.	8.0	1.5	13	385.	437.	394.	8.0	1.5
MAX DEPTH	7	386.	394.	274.	7.0	36.0	7	173.	227.	248.	7.0	37.2	7	324.	438.	395.	4.0	35.1
PH (STANDARD UNITS)																		
0.=1.5 M DEPTH	24	8.3	8.6	7.3	8.0	1.5	24	7.6	8.0	8.5	8.0	1.5	13	7.3	8.3	7.6	8.0	1.5
MAX DEPTH	7	8.3	7.6	7.3	7.0	36.0	7	7.6	7.7	7.5	7.0	37.2	7	7.3	7.8	7.6	4.0	35.1
TOTAL ALKALINITY (MG/L)																		
0.=1.5 M DEPTH	24	99.	398.	48.	8.0	1.5	24	32.	123.	48.	8.0	1.5	13	193.	226.	122.	8.0	1.5
MAX DEPTH	7	99.	248.	62.	7.0	36.0	5	32.	75.	41.	7.0	37.2	7	115.	188.	124.	4.0	35.1
TOTAL P (MG/L)																		
0.=1.5 M DEPTH	24	0.033	0.125	0.181	8.0	1.5	13	0.048	0.248	0.399	8.0	1.5	13	0.039	0.173	0.057	8.0	1.5
MAX DEPTH	7	0.043	0.134	0.119	7.0	36.0	5	0.030	0.248	0.105	7.0	37.2	7	0.037	0.196	0.178	4.0	35.1
DISSOLVED ORTHO P (MG/L)																		
0.=1.5 M DEPTH	24	0.021	0.074	0.095	8.0	1.5	24	0.022	0.071	0.05	8.0	1.5	13	0.020	0.073	0.035	8.0	1.5
MAX DEPTH	7	0.028	0.072	0.094	7.0	36.0	5	0.024	0.065	0.054	7.0	37.2	7	0.029	0.067	0.053	4.0	35.1
NO3+NO2 (MG/L)																		
0.=1.5 M DEPTH	24	0.037	0.058	0.125	8.0	1.5	24	0.028	0.058	0.048	8.0	1.5	13	0.039	0.078	0.068	8.0	1.5
MAX DEPTH	7	0.037	0.058	0.084	7.0	36.0	5	0.028	0.063	0.048	7.0	37.2	7	0.040	0.068	0.218	4.0	35.1
AMMONIA (MG/L)																		
0.=1.5 M DEPTH	24	0.033	0.208	0.134	8.0	1.5	24	0.040	0.138	0.075	8.0	1.5	13	0.029	0.087	0.060	8.0	1.5
MAX DEPTH	7	0.040	0.210	0.178	7.0	36.0	5	0.070	0.248	0.048	7.0	37.2	7	0.040	0.068	0.060	4.0	35.1
KJELDAHL N (MG/L)																		
0.=1.5 M DEPTH	24	0.620	0.958	0.724	8.0	1.5	13	0.409	0.788	0.668	8.0	1.5	13	0.485	0.888	0.728	8.0	1.5
MAX DEPTH	7	0.599	0.958	0.783	7.0	36.0	5	0.388	0.788	0.668	7.0	37.2	7	0.488	0.888	0.783	4.0	35.1
SECCHI DISC (METERS)	7	3.3	3.4	3.4			7	4.2	3.1	3.3			7	3.4	2.7	3.4		

* N = NO. OF SAMPLES
AT MAXIMUM DEPTH SAMPLED AT EACH SITE
MAX N = NO. OF SITES FOUND ON EACH DATE

[illegible] LAKE AT THE CHEAP
STREET CODE [illegible]

[illegible] AND CHEMICAL CHARACTERISTICS

PARAMETER	NP	(1982/[illegible]) MEAN	MEDIAN	MEAN DEPTH WEIGHTED	MIN	MAX
TEMPERATURE, DEG CENT						
0.0-1.5 M DEPTH	24	18.0> 19.3	19.2	0.0>	1.5	
MAX DEPTH	7	15.1> 16.7	17.1	7.0>	36.0	
DISSOLVED OXYGEN (MG/L)						
0.0-1.5 M DEPTH	24	6.1> 6.2	7.1	0.0>	1.5	
MAX DEPTH	7	6.2> 6.6	7.1	7.0>	36.0	
CONDUCTIVITY (UMHOS)						
0.0-1.5 M DEPTH	24	284.> 288.	253.	0.0>	1.5	
MAX DEPTH	7	264.> 285.	252.	7.0>	36.0	
PH (STANDARD UNITS)						
0.0-1.5 M DEPTH	24	7.5> 10.1	7.0	0.0>	1.5	
MAX DEPTH	7	7.5> 14.3	7.0	7.0>	36.0	
TOTAL ALKALINITY (MG/L)						
0.0-1.5 M DEPTH	24	81.> 124.	98.	0.0>	1.5	
MAX DEPTH	7	83.> 124.	98.	7.0>	36.0	
TOTAL P (MG/L)						
0.0-1.5 M DEPTH	24	0.034>0.229	0.054	0.0>	1.5	
MAX DEPTH	7	0.053>0.229	0.065	7.0>	36.0	
DISSOLVED OR PO P (MG/L)						
0.0-1.5 M DEPTH	24	0.024>0.044	0.032	0.0>	1.5	
MAX DEPTH	7	0.022>0.079	0.039	7.0>	36.0	
NO3+NO2 (MG/L)						
0.0-1.5 M DEPTH	24	0.535>1.286	0.720	0.0>	1.5	
MAX DEPTH	7	0.840>1.330	0.891	7.0>	36.0	
AMMONIA (MG/L)						
0.0-1.5 M DEPTH	24	0.020>0.258	0.025	0.0>	1.5	
MAX DEPTH	7	0.020>1.171	0.071	7.0>	36.0	
KJELDAHL N (MG/L)						
0.0-1.5 M DEPTH	24	0.209>1.280	0.350	0.0>	1.5	
MAX DEPTH	7	1.403>1.580	1.403	7.0>	36.0	
SECCHI DISC (METERS)	7	0.0> 0.0	0.0			

> = MIN. OF SAMPLES
MAX DEPTH SAMPLED AT 0.0> 1.5
NP = NO. OF DATES SAMPLED IN 7.0> DATE

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/02/74	1. Chroomonas	306
	2. Centric Diatom	279
	3. Melosira	223
	4. Scenedesmus	112
	5. Micractinium	111
	Other genera	139
	Total	1,170
06/14,17/74	1. Stephanodiscus	1,387
	2. Melosira	1,040
	3. Chlamydomonas	231
	4. Nitzschia	116
	5. Chroomonas	92
	Other genera	648
	Total	3,514
08/29/74	1. Oscillatoria	1,430
	2. Melosira	786
	3. Chroomonas	286
	4. Skeletonema	191
	5. Ankistrodesmus	167
	Other genera	939
	Total	3,799
10/21,22/74	1. Melosira	413
	2. Chroomonas	275
	3. Flagellate	184
	4. Ankistrodesmus	46
	5. Cryptomonas	46
	Other genera	344
	Total	1,308

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
04/08/74	01	0.4
	02	1.4
	03	3.1
	04	1.1
	05	5.8
	06	4.0
	07	10.5
06/14,17/74	01	11.1
	02	4.5
	03	5.6
	04	5.9
	05	2.2
	06	10.2
	07	8.7
08/29/74	01	2.9
	02	4.7
	03	4.9
	04	4.7
	05	5.8
	06	19.0
	07	24.9
10/21,22/74	01	1.8
	02	2.5
	03	6.2
	04	2.9
	05	12.4
	06	11.8
	07	8.5

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spiked(mg/l)	Ortho P Conc.(mg/l)	Inorganic N Conc.(mg/l)	Maximum Yield (mg/l-dry wt.)
a. 04/02/74 - Stations 01-04			
Control	0.055	1.130	6.2
0.05 P	0.105	1.130	7.8
0.05 P + 1.0 N	0.105	2.130	22.6
1.00 N	0.055	2.130	15.9
Stations 05-07			
Control	0.015	1.550	2.0
0.05 P	0.065	1.550	10.1
0.05 P + 1.0 N	0.065	2.550	13.2
1.00 N	0.015	2.550	2.9
b. 10/21/74 - Stations 01-04			
Control	0.027	0.535	5.7
0.05 P	0.077	0.535	11.5
0.05 P + 1.0 N	0.077	1.535	23.4
1.00 N	0.027	1.535	6.2

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential for primary production in Grand Lake o' the Cherokees was high during both spring and fall sampling. In the spring sample for Stations 05-07, and in the autumn assay, the addition of phosphorus alone produced a significant increase in yield over that of the control, indicating those samples were phosphorus limited. The addition of nitrogen alone did not result in any increase in yield over that of the control. In the spring assay sample for lake Stations 01-04, nitrogen limitation was indicated, as the addition of nitrogen alone produced the significant increase in yield over that of the control. In all assays, the maximum increase in yield was achieved with the simultaneous addition of both nutrients.

The mean inorganic nitrogen to orthophosphorus (N/P) ratios in the lake data were 15/1 or greater on all sampling occasions, suggesting primary limitation by phosphorus (a mean N/P ratio of 14/1 or greater generally reflects phosphorus limitation).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Oklahoma National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of May and June when two samples were collected at some stations. Sampling was begun in November 1974, and was completed in October 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Oklahoma District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries, except Lost Creek, F-1, were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) and Lost Creek, F-1, were estimated by using the mean annual nutrient loads, in kg/km^2/yr, in Buffalo Creek, Elk River, and Honey Creek, at Stations H-1, J-1, and K-1, and multiplying the means by the ZZ area in km^2.

The operators of the Miami (2 plants), Fairland (2 plants), Grove, Minot, and B.F. Goodrich wastewater treatment plants

provided monthly effluent samples and corresponding flow data. Nutrient loads for the Afton, Miami #3, Jay, Seneca (2 plants), Quapaw, Commerce, Cardin, Picher, and Joplin wastewater treatment plants were estimated at 1.134 kg P and 3.401 kg N/capita/yr.

A. Waste sources:

1. Known municipal:

Name	Population Served*	Treatment*	Mean Flow ($m^3/d \times 10^3$)	Receiving Water
Miami #1	13,000	Trickling filter	3.052	Neosho River
Miami #2		Activated sludge	1.893	Tar Creek/Neosho River
Miami #3	1,200	Stabilization pond	0.454**	Neosho River
Afton	800	Trickling filter/ tertiary	0.303**	Horse Creek
Fairland #1	1,000	Imhoff tank	0.022	Honeycomb Creek
Fairland #2		Stabilization pond	0.408	Hudson Creek
Grove	1,400	Trickling filter	0.425	Grand Lake
Jay	875	Stabilization pond	0.331**	Muskrat Hollow/ Drowning Creek
Seneca (Mo.)	1,700	Stabilization pond	0.643**	Lost Creek/Grand Lake
Seneca Indian School	200	Stabilization pond	0.076**	Lost Creek/Grand Lake
Quapaw	800	Trickling filter	0.303**	Spring River
Commerce	2,100	Imhoff tank/ trickling filter	0.795**	Tar Creek
Cardin	200	Stabilization pond	0.076**	Tar Creek
Picher	1,500	Stabilization pond	0.568**	Tar Creek
Joplin	7,000	Trickling filter	2.650**	Shoal Creek/Spring Creek

2. Known industrial:

Name	Product	Treatment	Mean Flow, ($m^3/d \times 10^3$)	Receiving Water
Hilmot Company (Seneca)	Milk Processing	Trickling filter	1.418	Lost Creek
B.F. Goodrich (Miami)	Tires, Rubber	Stabilization pond	3.980	Neosho River

*Provided by plant operators and/or U.S EPA (1971).
**Estimated at 0.3785 m^3/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (nonpoint load) -		
A-0 Neosho River	813,170	82.7
B-1 Horse Creek	4,075	0.4
C-1 Tar Creek	15,115	1.5
D-1 Spring River	385,700	39.2
E-1 Lost Creek	2,336	0.2
F-1 Buffalo Creek	1,510	0.1
G-1 Elk River	29,555	3.0
H-1 Honey Creek	1,330	0.1
b. Minor tributaries and immediate drainage (nonpoint load) -	18,625	1.9
c. Known municipal STP's -		
Miami #1	9,355	0.9
Miami #2	3,580	0.3
Miami #3	1,360	0.1
Afton	905	0.1
Fairland #1	75	<0.1
Fairland #2	830	0.1
Grove	2,195	0.2
Jay	930	0.1
Seneca (Mo.)	1,930	0.2
Seneca Indian School	225	<0.1
Quapaw	503	0.1
Commerce	2,680	0.2
Cardin	225	<0.1
Picher	1,700	0.2
Joplin	7,940	0.8
d. Septic tanks* -	80	<0.1
e. Known industrial -		
Wilnot Co.	12,030	0.9
B.F. Goodrich (Miami)	555	<0.1
f. Direct precipitation** -	3,295	0.2
Totals	1,297,850	100.0
2. Output - A-1 Neosho River	804,480	
3. Net annual P accumulation -	813,370	

*Estimate based on 219 lakeshore residences.
**Estimated (see NES Working Paper No. 176).

C. Annual Total Nitrogen Loading - Average Yrs.[1]

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (nonpoint load[1]) -		
A-2 Neosho River	6,645,795	48.9
B-1 Horse Creek	88,360	0.7
D-1 Tar Creek	60,365	0.4
E-1 Spring River	4,750,590	35.0
F-1 Lost Creek	87,575	0.6
H-1 Buffalo Creek	81,440	0.6
J-1 Elk River	983,280	7.2
K-1 Honey Creek	46,210	0.3
b. Minor tributaries & immediate drainage (nonpoint load) -	585,975	4.3
c. Known municipal STP's -		
Miami #1	23,270	0.2
Miami #2	10,270	0.1
Miami #3	4,080	<0.1
Afton	2,720	<0.1
Fairland #1	145	<0.1
Fairland #2	1,785	<0.1
Grove	3,975	<0.1
Jay	2,975	<0.1
Seneca (Mo.)	5,780	<0.1
Seneca Indian School	680	<0.1
Quapaw	4,720	<0.1
Commerce	7,140	0.1
Cardin	680	<0.1
Picher	3,100	<0.1
Joplin	85,805	0.6
d. Septic tanks[2] -	2,335	<0.1
e. Known industrial -		
Minot Company	2,005	<0.1
B.F. Goodrich (Miami)	2,020	<0.1
f. Direct precipitation[3] -	203,180	1.5
totals	13,583,175	100.0
2. Output - A-1 Neosho River	10,157,185	
3. Net annual N accumulation -	3,425,990	

[1]Estimate based on 219 lakeshore residences.
[2]Estimated (see NFS Working Paper No. 175).

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Neosho River	53	437
Horse Creek	77	595
Tar Creek	170	680
Spring River	55	211
Lost Creek	10	375
Buffalo Creek	6	325
Elk River	12	435
Honey Creek	11	364

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P (mg/l)	Mean Total N (mg/l)
G-1 Ogeechee Creek	0.117	1.181
G-1 Sycamore Creek	1.616	6.484

Phosphorus levels for both Ogeechee and Sycamore Creeks, and nitrogen levels for Sycamore Creek were substantially higher than the unimpacted gaged tributaries (Buffalo Creek, Elk River, Honey Creek) to Grand Lake o' the Cherokees. Ogeechee Creek receives input from the Fairland sewage treatment facilities; the reason for inflated nutrient levels in Sycamore Creek is not known.

F. Yearly Loadings:

In the following table, the existing phosphorus annual loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his "eutrophic" loading is that at which the receiving waters would become eutrophic or remain eutrophic; his "oligotrophic" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A "mesotrophic" loading would be considered one between "eutrophic" and "oligotrophic".

Note that Vollenweider's model may not be applicable to water bodies with very short retention times or in which light penetration is severely restricted from high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading ($g/m^2/yr$)
Estimated loading for Grand Lake o' the Cherokees	6.90
Vollenweider's "eutrophic" loading	1.00
Vollenweider's "oligotrophic" loading	0.54

V. LITERATURE REVIEWED

Ketelle, Martha J. and Paul O. Uttormark. 1971. Problem Lakes in the United States. U.S. Environmental Protection Agency, Project #16010 EHR. University of Wisconsin, Madison, Wisconsin.

U.S. Environmental Protection Agency. 1971. "Inventory of Wastewater Treatment Facilities", EPA Publication No. OWP-1, Volume 6. Office of Media Programs, Office of Water Programs, Washington, D.C.

U.S. Environmental Protection Agency. 1975. National Eutrophication Survey Methods 1973-1976. Working Paper No. 175. National Environmental Research Center, Las Vegas, Nevada, and Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

Vollenweider, R. A. 1975. Input-Output Models With Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrol. 37:53-84.

VI. APPENDICES

APPENDIX A
CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 0.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B
TRIBUTARY FLOW DATA

APPENDIX C
PHYSICAL AND CHEMICAL DATA

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DATE FROM TO	TIME OF DAY	DEPTH FEET	BIOMASS PHEOPHYTIN MG/L	CHLOROPHYLL A MG/L	CHECK (ACID LOSS BY PERCENT)
[illegible]	11 05	[illegible]	[illegible]	[illegible]	
	11 55	[illegible]	[illegible]		
	11 05	[illegible]	[illegible]		
	11 05	[illegible]	[illegible]		
	11 05	[illegible]	[illegible]		
[illegible]	24 11	[illegible]	[illegible]	[illegible]	
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40041 OKLAHOMA
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DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/??	15 15	0000	0.086	5.0	
	15 15	0005	0.077		
	15 15	0015	0.080		
	15 15	0030	0.081		
	15 15	0046	0.085		
74/08/17	11 05	0000	[illegible]	2.2	
	11 05	0005	[illegible]		
	11 05	0015	[illegible]		
	11 05	0035	[illegible]		
	11 05	0047	[illegible]		
74/08/29	15 25	0000	[illegible]	4.0	
	15 25	0005	[illegible]		
	15 25	0007			1.0
	15 25	0015	[illegible]		
	15 25	0040	[illegible]		
74/10/22	10 35	0000	[illegible]	12.4	
	10 35	0005	[illegible]		5.0
	10 35	0007			1.0
	10 35	0015	[illegible]		
	10 35	0020	[illegible]		
	10 35	0042	[illegible]		

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GRAND LAKE O' THE CHEROKEES
40115 OKLAHOMA
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74/04/02	14 10	0000	0.102	11.5	
	14 10	0005	0.096		
	14 10	0015	0.096		
	14 10	0025	0.105		
74/06/17	14 20	0000	0.130	6.7	
	14 20	0013			1.0
	14 20	0005	0.130		
	14 20	0015	0.144		
	14 20	0025	0.100		
74/08/29	15 05	0000	0.173	26.4	
	15 05	0002			1.0
	15 05	0005	0.173		
	15 05	0013	0.196		
74/10/22	11 15	0000	0.226	4.5	
	11 15	0005	0.217		
	11 15	0015	0.215		
	11 15	0023	0.226		

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APPENDIX D

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

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[illegible]	[illegible]	FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7/ 7/1984	12	25	1.606	8.388	1.438	1.425	0.946
7/ 7/1984	14	38	1.321	8.386	1.810	1.815	0.825
7/ 8/1984	17	07	1.118	8.458	1.389	1.625	1.438
7/ 8/1984	18	21	1.156	8.598	1.846	1.819	0.858
7/ 9/1984	09	36	1.101	8.418	1.832	1.809	0.948
7/ 9/1984	10	35	1.671	8.716	1.821	1.815	0.939
7/10/1984	08	17	1.638	8.399	1.823	1.826	0.838
7/10/1984	09	15	8.758	1.858	1.816	1.815	0.858
7/11/1984	09	18	1.448	8.758	1.845	1.836	0.858
7/11/1984	10	11	1.580	8.488	1.815	1.846	1.879
7/12/1984	13	13	1.634	1.381	1.825	1.822	0.946

* [illegible]
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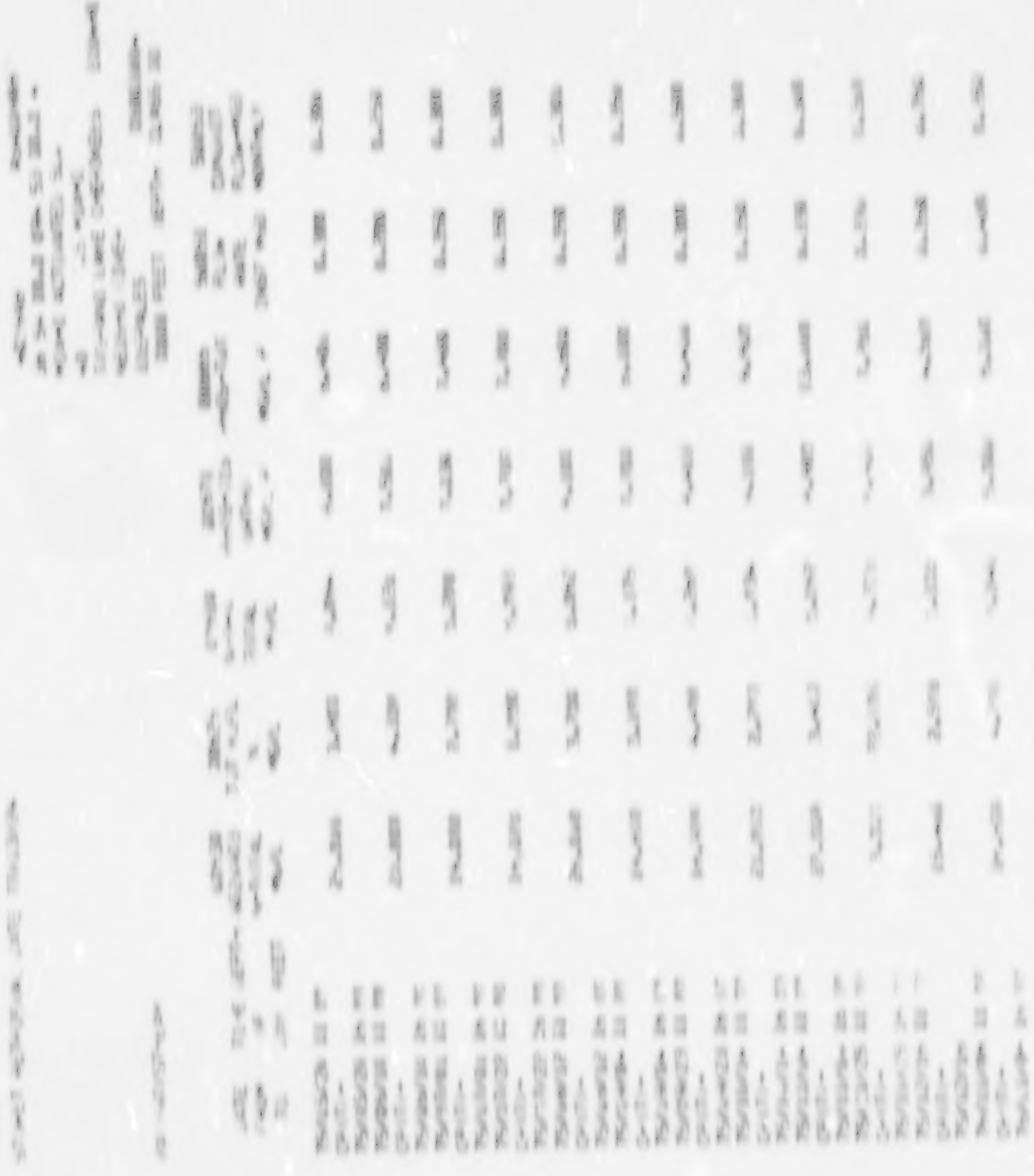

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APPENDIX E

PARAMETRIC RANKINGS OF LAKES SAMPLED BY NES IN 1974

STATE OF OKLAHOMA